Sucked trumpets in prehistoric Europe and North America? A technological, acoustical and experimental study

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Abstract
In the Hornbostel-Sachs system of musical instrument classification, the aerophones proper are presumed to be blown instruments. Several trumpets from northern Eurasia, North America and South America, however, have traditionally been played in the opposite way, by inhaling. These sucked trumpets, counting among lip-vibrated instruments, have been used for calling game, as well as playing melodies. This article presents prehistoric bone artefacts from Ajvide, Gotland, Sweden (c. 2900–2300 cal. BC) and Eva, Benton county, Tennessee (5700–4700 BC), and discusses whether they could be regarded as early examples of sucked trumpets. The tubular artefacts are made from swan (Cygnus sp.) and wild turkey (Meleagris gallopavo) ulnae and radii by cutting, scraping and filing the bones and fitting them together. Similar two-piece structure turns up in the traditional wing bone turkey calls used to this day by North American hunters. The copies of the artefacts produce a variety of clucking, yelping and trumpeting sounds, when played with the sucking technique. The two-piece structure could have an acoustic motive or meaning, as it enables to make the sound louder and to modify the tone colour.

1 Introduction

Sucked trumpets could certainly be counted among the most extraordinary musical instruments. Instead of being blown, they are played by inhaling, by sucking in air through a hollow tube. The tightly puckered lips of the player generate the sound, just as with conventional trumpets, but the lips vibrate backward rather than forward.[1] Consequently, organologists have had dissenting opinions on how to incorporate these instruments in the Hornbostel-Sachs system of musical instrument classification (Tab. 1).[2] Although rare, sucked trumpets are found almost all over the world. Ethnographic examples include the *byrgy* hunting horns from Siberia,[3] the *yus' pöl´an* swan calls from northeast Europe,[4] the traditional wing bone turkey calls from North America,[5] as well as the *nolkin*, *chirimía* and other objects from South America.[6] As one end of the tube must be inserted between the player's lips, all these instruments have an extremely narrow bore, only a few millimetres at the mouth end. The rest of the tube – made from bark, wood or stalk – is often slightly conical or flaring, or equipped with a bell-like appendage. In the traditional wing bone turkey calls, two or three cylindrical bone tubes have been telescoped to form a kind of stepped cone.

[1] Leisiö 1998, fig. 1.
[2] Schneider 1993, 78–80; Leisiö 1998, 64–66; Pérez de Arce – Gili 2013, apéndice 21.
[3] Leisiö 1993; Leisiö 1998.
[4] Leisiö 1998, 66–69.
[5] Harlan 1994, 31–36. 62–65. 92–97. 152–154; Williams Jr. 1996, 165–203; Hickoff 2009, 18–21. 83–84.
[6] Izikowitz 1935, 218–219; Schneider 1993; Pérez de Arce 2007, 276–281; Pérez de Arce – Gili 2013, fig. 8.

Wing bone turkey calls are still used by North American hunters, who treasure old traditions (Fig. 1). The ethnographic fieldwork records of Frank G. Speck[7] state that the Native Americans of Virginia used the second section of the wing bone for calling wild turkey, and the practice became common in the 19th and20th centuries, thanks to several hunters' guidebooks and magazines.[8] According to instructions found in the literature and the internet,[9] wing bone calls are made using two bones from the second section of the wing by inserting a narrower radius into a broader ulna (Fig. 2). These two bones seem to fit together almost naturally, without too much trimming. An additional humerus – from the first wing section – can act as an end-piece if a three-piece call is preferred. The radius alone can be used as a simple mouse squeaker to attract fox. Traditional one-piece calls from New Mexico often have a finger hole,[10] but otherwise the calls are always unperforated. The wing bone calls are used to lure turkeys within shooting distance by imitating their sounds. Mating, assembly and social calls, as well as the cries of immature individuals, can be used for the purpose.[11]

This article discusses the telescoped bird bone tubes found at the prehistoric sites of Ajvide, Gotland, Sweden, and Eva, Tennessee, United States.[12] These artefacts, made from the wing bones of swan (*Cygnus sp.*) and wild turkey (*Meleagris gallopavo*), bear a striking resemblance to the Native American wing bone turkey calls in relation to structure, size and choice of material. Their two-piece structure has few parallels in the archaeological and ethnographical record and can hardly be explained by any decorative- or manufacturing tool-related reasons. An acoustic reason – on the model of the wing bone turkey calls – is, however, worth studying. The article examines the purpose and use of the Ajvide and Eva artefacts by 1) tracing the *chaîne opératoire* of their makers,[13] and 2) testing the playability of copies as sucked trumpets. More generally, the topic aims to bring sucked trumpets up for discussion concerning prehistoric aerophones, bone pipes and their voicing methods.[14]

2 Study material

The Ajvide site is situated on the western coast of the island of Gotland and consists of settlement remains (c. 3100–2700 cal. BC), activity areas and a total of eighty-five graves (c. 2900–2300 cal. BC).[15] Culturally, the people found at this site were part of the Scandinavian Pitted Ware tradition, displaying a hunting-fishing-gathering economy.[16] In grave 62, a cluster of 44 bird bone tubes, ten of them perforated, was found near the right arm and around the skull and shoulders of a 25–30-year-old female (Fig. 3).[17] Ten of these tubes were fitted together to form two-piece artefacts.[18] Three of the two-piece artefacts were made using only unperforated tubes (Figs. 4, 5), while two of the two-piece artefacts consist of one perforated and one unperforated tube (Fig. 6). Several other tubes found separately could be parts of broken two-piece artefacts. The unique set of grave 62 was published as flutes by the

[7] Speck 1928, 356–358.
[8] Harlan 1994, 31–36. 94–96.
[9] Williams Jr. 1996, 165–203; Miniter 1998; Patton 2002; Hickoff 2009, 18–21. 83–84; Hodges 2012; Young 2012.
[10] Jeancon 1923, 27 Pl. 29, A–B.
[11] McIlhenny 1914, 185–197; Hickoff 2009, 36–55.
[12] Österholm 1998; Burenhult 2002, 116–117 fig. 109, 8–11; Mannermaa – Rainio 2013, Table 14, 2; Lewis – Kneberg Lewis 1961, 84 pl. 38, f–l.
[13] E.g. Inizan – Roche – Tixier 1992.
[14] Cf. Münzel – Seeberger – Hein 2002; Lawson – d'Errico 2002; Ringot 2012; Wyatt 2012.
[15] Burenhult 1997; Burenhult 2002; Österholm 2008; Norderäng 2009.
[16] Olson *et al*. 2002; Storå 2002; Mannermaa – Storå 2006.
[17] Burenhult 2002, 116–117 fig. 109, 8–11; Molnar 2002, 373.
[18] Mannermaa – Rainio 2013; Rainio – Mannermaa 2014.

finders, Inger Österholm and Göran Burenhult.[19] Later studies[20] have challenged this interpretation, stating that the finger-hole-like perforations – always six in number – are absolutely unsuitable for finger holes because they are placed on both sides of the tubes, three per side precisely opposite each other. The unperforated artefacts, nevertheless, can be sounded as end-blown flutes. A probable two-piece artefact was also found in grave 25, on the neck of a 30–35-year-old male.[21]

The Eva site is located in Benton County, Tennessee, along an ancient channel of the Tennessee River. It consists of an extensive settlement site occupied by hunter-fisher-gatherers over a period of several thousand years (c. 8000/6000–1000 BC).[22] Telescoped bird bone artefacts, nine in number and all unperforated, were mostly found in an early stratum dated to the Middle Archaic period (5700–4700 BC) (Fig. 7).[23] They are not as well-preserved as the Ajvide artefacts, but were made in the same way by fitting two wing bones together. The Eva artefacts were published by their finders Thomas Lewis and Madeline Kneberg Lewis[24] as possible slide whistles. Turkey call maker and collector Howard L. Harlan,[25] however, noticed their striking similarity to traditional suction type wing bone calls, and regarded them as early examples of this type. At least three similar artefacts have been found at other prehistoric sites in Tennessee.[26]

3 Methods

The two-piece bone artefacts from Ajvide and Eva were studied at Gotland Museum, at Gotland University, and at the Frank H. McClung Museum at the University of Tennessee. In Gotland, osteologist Dr. Kristiina Mannermaa identified the bones with the aid of a reference bird skeleton collection assembled at the Finnish Museum of Natural History, confirming that the Ajvide artefacts were made from the ulnae and radii bones of swan wings.[27] In Knoxville, Tennessee, Prof. Walter E. Klippel expressed an advisory opinion that the Eva artefacts were similarly made from wild turkey ulnae and radii. All two-piece artefacts from Ajvide and Eva (Tab. 2),[28] as well as several one-piece tubes and tubular beads from both sites, were studied with a microscope at 10.5x magnification to detect traces of manufacture and use. All of the specimens were also measured, weighted and photographed.[29]

Based on this documentation, several copies and reference tubes were prepared for testing purposes. These represent different size categories as well as artefact categories: 1) two-piece, unperforated, 2) two-piece, perforated in the Ajvide style, 3) one-piece, unperforated, 4) one-piece, perforated in the Ajvide style. These copies and test tubes were made from swan (*Cygnus olor*), goose (*Branta leucopsis*), gull (*Larus argentatus, Larus canus*) and wild turkey humerii, ulnae and radii using both flint tools and modern files. Using various flint blades and points made it possible to attempt a duplication of the original manufacturing techniques as well as to identify the marks appearing on the bones. The finished artefacts were tested and recorded both outdoors and at the studio of the University of Helsinki Music

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[19] Österholm 1998; Burenhult 2002, 116–117.
[20] Jonasson 2000; Mannermaa 2008, 210–211; Mannermaa – Rainio 2013; Rainio – Mannermaa 2014.
[21] Österholm 2008, 45.
[22] Lewis – Kneberg Lewis 1961; Faulkner 2010.
[23] Lewis – Kneberg Lewis 1961, 13. 84. 173 tab. 13. 14.
[24] Lewis – Kneberg Lewis 1961, 84.
[25] Harlan 1994, 92–93 pl. 7, 1.
[26] Harlan 1994, 35 pls. 3, 7–8; cf. also Martin 1976, 56–57.
[27] Cf. Mannermaa – Rainio 2013; Rainio – Mannermaa 2014.
[28] The study material comprises five two-piece artefacts from Ajvide grave 62, and seven two-piece artefacts from Eva. The excavators report nine two-piece artefacts from Eva, but two of them could not be traced at the museum.
[29] An analysis of all bone tubes from Ajvide grave 62 was published in Rainio – Mannermaa 2014.

Research Laboratory with the help of two Neumann KM 183 condenser microphones, a Zoom H6 digital recorder (96 kHz/24 bit), and a calibrated Amprobe SM-20 sound level meter. Finally, the recorded sound files were analysed with the Spectutils sound analysis and visualization software toolkit, which builds on GNU Octave numerical computation language and provides functions for creating oscillograms -as well as spectrograms and sonograms based on short time Fourier transforms.[30]

4 Identifying the manufacturing technique

On the basis of the microscopical study, the artefacts from Ajvide and Eva are highly similar, and made following almost the same *chaîne opératoire*. As raw material, the makers at both sites selected wing bones from large birds, which are long, straight and naturally hollow. The ulna and radius from the second wing section were especially suitable for making two-piece tubular artefacts since they have slightly different diameters (ulnae 8–13 mm, radii 5–9 mm), but similar curves. In addition, the diameter of a swan and wild turkey radius is ideal for sucking. Straight horizontal striations along the shafts indicate that at an early stage the bones were scraped clean and shaped into a smooth, less ridged form (Fig. 8). This shaping is especially clear on the inner tubes, the radii, which are usually entirely striated (Fig. 9). It could be related to the trimming needed to make two bones fit properly. In the beads and other tubular bone artefacts from Ajvide and Eva, similar striations cannot be seen.

At the next stage, the bones were cut into shorter pieces. Based on an interpretation of the many saw marks, this was accomplished by sawing a circular groove, or a couple of grooves, around the bone before snapping it in two. The radii were often cut somewhat shorter (L 30–60 mm) than the ulnae (L 55–105 mm). At Eva, the makers seem to have removed mainly the epiphyses of the c. 120 mm long turkey bones, but at Ajvide the swan bones were chopped into two, three or four separate pieces. This suggests that the makers – at least at Ajvide – did not telescope the bones in order to obtain unusually long tubes, but for some other reason. Using the full length of a swan ulna or radius, it would have been easy to make even 200 mm long tubes.

After cutting the bones, their interior was completely cleaned of marrow and possibly of a network of internal bone. Smooth and rounded edges in the Ajvide artefacts suggest that the ends were also deliberately ground and filed both on the inside and outside of the tube (Fig. 10). In the Eva artefacts, the ends are usually broken, but at least one radius is clearly equipped with a U-shaped notch (Fig. 11). Similar notches, as well as double notches on the opposite sides of one end, are found on individual Ajvide radii, too (Fig. 12). These features are common to all aerophones because they improve the playability.[31] In mouthpieces, all rough protrusions and irregularities which could harm the lips are sanded down. The inner rims and inner surfaces, which house the air column, are carefully cleaned. In sucked trumpets, single or double notches are useful, as they fit comfortably against the sloping edges of the lips, thus helping to create an airtight seal.[32] Perforations in some of the Ajvide artefacts were made by sawing perpendicularly to the tube's axis.

At the final stage, the prepared bones were fitted together by sticking one end of the radius into the ulna for a length of about 10–40 mm. In most cases, the joint appears to be snug and firm, but occasionally the narrow radius moves or sways in place. This suggests that originally some extra material – like pine resin in traditional wing bone turkey calls[33] – could have been used to seal the joint.

[30] Lassfolk – Uimonen 2008.
[31] McIlhenny 1914, 183; Brown 1984, 770 fig. 1; Cooke – Schechter 1984, 776; Williams 1996, 171. 175–180. 202; Münzel – Seeberger – Hein 2002, 108; Hickoff 2009, 20–21.
[32] Schneider 1993, 71. 74; cf. Leisiö 1998, 66–67.
[33] Patton 2002.

Traces of such material, however, can no longer be found. In the best preserved artefacts, both components, ulna and radius, make up approximately half of the bore length,[34] and the total length of the artefacts is 95–135 mm. The stepped cone angle is about 1–1.5 degrees. In the two perforated artefacts, the tubes with perforations do not really add to the total length. Therefore, it seems possible that these perforated tubes have moved or slid from their original place. Basically, the same could also have happened with the unperforated artefacts.[35] The present-day wing bone turkey calls seem to be a bit larger than the prehistoric artefacts, as the total length of the two-piece calls is approximately 150–200 mm, and the three-piece calls are naturally longer.[36] As far as I know, this type of two-piece structure is almost unknown in the archaeological and ethnographic literature. For threaded tubular beads, the two-piece artefacts of Ajvide and Eva are certainly too large and clumsy.

5 Playing the copies and test tubes

Based on experiments, the copies of the Eva artefacts and the unperforated Ajvide artefacts function efficiently as sucked trumpets. Mastering the sucking technique is not necessarily easy at first, but with a little of serious practice it is possible to make clucking, yelping, honking and finally long trumpeting sounds. Smacking the lips, dropping the jaw and drawing in air with the throat will all produce different sounds or noises, most of which resemble the vocalization of a large bird. The narrower the mouthpiece, the easier the sound production. The one-piece test tubes of narrow gull bones (OD 4–5 mm,) produce the longest tones, lasting 0.5–1.2 seconds, but the swan and wild turkey radii (OD 5–9 mm) are also perfect for sucking. The swan and wild turkey ulnae and humerii (OD 8–18 mm), on the other hand, can hardly be sucked because it is difficult to insert such broad tubes between the lips. They only produce short clucks lasting 0.2–0.3 seconds. Thus, the sounds from the sucked trumpets, in general, are fairly short. The perforated copies and test tubes are not playable at all, because the numerous perforations on both sides of the tubes break up the vibrating air column.[37]

A striking feature is that the sound of all unperforated copies, as well as all playable test tubes, is extremely loud. In test occasions in the woods, the sound easily carries 350–400 m. Indoors it is loud enough to almost hurt the ears. However, there seems to be, in this respect, an audible and measurable difference between the one-piece and two-piece artefacts. When a one-piece test tube 114 mm in length produces a series of clucking sounds, the A-weighted sound pressure level at a distance of one metre rises to 74.6 dB (Tab. 3). When a two-piece tube of the same length produces a similar series of sounds, the sound pressure level at a distance of one metre rises to 83.4 dB.[38] While a single swan radius of 114 mm generates 74.6 dB, a single swan ulna of the same length generates 83.4 dB. Considering that the decibel scale is logarithmic, these differences are notable. They mean that the sound from a two-piece tube – as well as from a broad ulna – is approximately twice as loud as in the one-piece case (Fig. 13). Thus, it seems that by adding a broader appendage to the narrow mouthpiece it is possible to make the sound louder. The outer tube with a larger wind passage acts as a kind of amplifier. The *byrgys*, *nolkins* and other long sucked trumpets often have a wider – sometimes bell-like – ending,[39] which obviously increases the sound volume.

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[34] Or the radius makes up a bit more, approximately 60 %.

[35] As several Eva artefacts have glue on their surface, it seems that the inner and outer tubes were glued together after excavation. An open question is whether the joints were tight or loose before the gluing.

[36] Cf. Williams 1996, fig. 6, 9. 6, 16. 6, 22. 6, 24. 6, 26. 6, 28.

[37] The perforated two-piece artefact 34704 works – acoustically – as an unperforated one-piece tube.

[38] A shorter one-piece tube (L 100 mm) with the same fundamental frequency (860 Hz) generates 75.0 dB.

[39] Schneider 1993, 70 fig. 1; Leisiö 1998.

A spectral analysis of the honking and trumpeting tones shows a well-distributed set of partials, which pretty closely approximates the harmonic series (Fig. 14). The frequencies of these partials – from ten to twenty in number – are whole-number multiples of the fundamental frequency, which in the two-piece copies range around 700–1000 Hz. In the equally long one-piece test tubes, the fundamental is a couple of steps (200–400 cents) lower. The two-piece structure thus seems to raise the pitch a bit. A more important difference between the one-piece and two-piece artefacts turns up in tone colour, that is, the relative strength of the partials. As a one-piece tube has a cylindrical, closed air column, it accentuates or produces primarily odd-numbered partials (Fig. 15).[40] As a result, tone colour is nasal and clarinet-like. As a two-piece tube has a kind of conical, closed air column, it produces both odd- and even-numbered partials with a strong emphasis on the second partial, and sometimes also on the fourth partial (Fig. 16).[41] This emphasis, multiplying the pitch of the fundamental, makes tone colour simple and pure. Thus, by adding a broader appendage to the narrow mouthpiece, it was possible to modulate the timbre, to create a stepwise conical bore that evokes a pure tone colour with strong first and second harmonics.
Only one pitch can be played with the copies and test tubes, as they seem to be too short for 'overblowing', and the perforations in some of the tubes are unsuitable for finger holes, that is, for obtaining several pitches. However, a descending glide, characteristic of sucked trumpets, can easily be produced by loosening the lips at the end of each sound. This glide often happens quite accidentally, without any planning. In addition, the sound can be modulated by cupping both palms over the farther end of the tube. This, for example, dampens the highest partials (20. 000–37. 000 Hz).

6 Summary of results and field experiments
The microscopical study at the museums indicates that the makers of the Ajvide and Eva artefacts were working according to a more or less similar plan. As raw material, they chose bones that were suitable for tubular artefacts, especially for making two-piece tubes. They scraped, cut, smoothed and notched the bones so that they were – apart from the perforated specimens – easily playable as aerophones. Finally, they joined two bones together into an artefact that closely resembles a particular type of sucked trumpet traditionally used for calling a game bird. This circumstantial evidence, however, does not prove that the Ajvide or Eva artefacts were destined or used for sound production. Possible counterarguments are related to the unresolved function of the perforations in two Ajvide two-piece artefacts, as well as to the role of the numerous one-piece tubes in the same grave. All one-piece tubes in the grave are hardly parts of broken two-piece artefacts. However, these problematic tubes, both perforated and unperforated, might be regarded as beads that decorated the mouthpiece or some kind of carrying strap or neck lanyard. According to instructions for making traditional turkey calls, discarded extra pieces of cut bones are often threaded on the lanyard of the call, or slipped over the mouthpiece to hold the lanyard in place (cf. Fig. 1c).[42] The Eva material with almost uniform, unperforated tubes is not problematic in that way.
The experiments with the copies show that the unperforated Ajvide and Eva artefacts would have been effective sound producers if played using a sucking technique. The sound of all copies is very loud. The narrow radius is perfectly suitable as a mouthpiece. The broader ulna, for its part, further amplifies the sound and modifies the tone colour so that it becomes pure. These observations are noteworthy, because they propose an acoustic reason for the two-piece structure of the artefacts. Other relevant

[40] Cf. Rossing – Moore – Wheeler 2002, 135–136. 252–253 fig. 12, 7 tab. 12, 1.
[41] Cf. Rossing – Moore – Wheeler 2002, 135–136. 252–253 fig. 12, 7 tab. 12, 1.
[42] Miniter 1998; Patton 2002, 47; Young 2012.

reasons or interpretations are few in number and similarly relate to sound production. In so-called slide whistles, the inner tube serves as a piston that changes the pitch.[43] Such instruments, however, could hardly be made of bone material. In the *igemfe* end-blown flutes from South Africa, the outer tube serves as the mouthpiece, but further understanding of the *igemfe* acoustics would demand a study of its own.[44]

Playable copies and test tubes offer various possibilities for producing different kinds of sucked sounds: from noisy clucks, yelps and cries to trumpeting tones and honks with a harmonic structure (Tracks 1–3). These bird-related characterizations are of course subjective, but somewhat supported by the experiences in the field. In several test occasions in the woods, a raven (*Corvus corax*), crow (*Corvus corone*), magpie (*Pica pica*), great tit (*Parus major*) or some other curious species got close to the player. A couple of times whooper swans (*Cygnus cygnus*) appeared to be answering from afar, where they had a nest. Thus, it seems quite reasonable to believe that the loud sound of the sucked trumpet could be used for luring or locating birds. To succeed in that, the behavior of the subject species had to be learnt carefully.[45] Short noisy clucks produced with the copies could certainly imitate wild turkeys or some other gallinaceous birds. Longer trumpeting tones could imitate the calls of swans, geese, hawks and gulls, as these families make sounds with a clear harmonic structure.[46] The fundamental of swan vocalizationis in the range of 600–900 Hz, which more or less corresponds with the fundamental of the Ajvide artefacts. The descending glide, on the other hand, is typical of hawks and gulls. Furthermore, a cursory examination of the bird vocalizations in the electronic sound archives suggests that the harmonic spectrum of the above-mentioned birds is rather pure in colour, consisting of both odd- and even-numbered partials, as well as strong first and second partials.

7 Final remarks

Although not explicitly solving the question of ancient purpose of use, the technological and acoustical analyses above show that the two-piece artefacts of Ajvide and Eva have strong acoustic potential. When played with a sucking technique, copies produce loud and carrying sounds or noises that attract different bird species from the neighbouring woods toward the player. Taking into account the similarity between these artefacts and Native American wing bone turkey calls, it seems quite reasonable to assume that instruments like this have been known and used for ages in North America. The Eva artefacts might well represent early examples.

In Europe, the only known sucked trumpets are the *yus' pöl´an* and *čipčirgan* of the Komis and Udmurts, who made these instruments from the stalk of a vascular plant.[47] Earlier examples of the type could have been similarly made from easily perishable materials that leave no traces in the archaeological record. The extraordinary bone tubes of Ajvide might cast some light on the shrouded history of European sucked trumpets, especially if more two-piece specimens are found in the future. The Ajvide finds alone – with the confusing perforated specimens – might not be seen as sufficiently conclusive evidence. Anyhow, the category of sucked trumpets should be regarded as a relevant alternative when seeking an acoustical explanation for enigmatic archaeological bone tubes – especially if they have a telescoped structure.

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[43] Leisiö 1983, 39. 118–119. 154.
[44] Rycroft 1984, 280–281.
[45] Cf. Lund 1988; Tamboer 2004.
[46] Vogels van… 1993, tracks 6. 26; XC 42599; XC 49799; XC 118355; XC 125486; XC 149169; XC 164594; XC 164595; XC 167764; XC 167866; XC 167878; XC 180279; XC 193095; XC 196982.

[47] Leisiö 1993; Leisiö 1998, 66–69.

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Fig. 1. Wing bone turkey calls made by Jim Young, Auburn, New York. a) Two-piece call, a standard model. b) Two-piece call with a rawhide-wrapped joint. c) Hand polished two-piece call with a neck lanyard and bone attachments (the length of the calls is c. 190 mm) (Photo by R. Rainio).

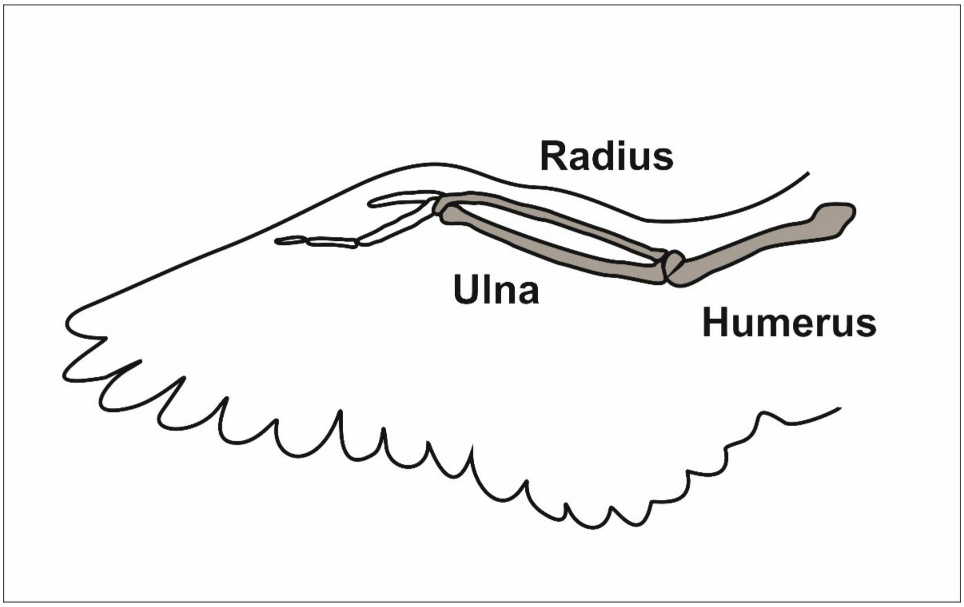

Fig. 2. Bones in a bird wing (Drawing by R. Rainio).

Fig. 3. Grave 62 at Ajvide. Tubular bone artefacts were found in a find concentration near the right arm and around the skull and shoulders. Reconstruction at Gotland Museum (2006) (Photo by K. Mannermaa).

Fig. 4. Two-piece tubular bone artefact 34648 made of the ulna and radius of a swan (*Cygnus* sp.) from Ajvide grave 62 (Photo by J. Norderäng).

Fig. 5. Two-piece tubular bone artefact 34649 made of the ulna and radius of a swan (*Cygnus* sp.) from Ajvide grave 62 (Photo by J. Norderäng).

Fig. 6. Two-piece tubular bone artefact 34704 made of the ulna and radius of a swan (*Cygnus* sp.) from Ajvide grave 62. Reconstruction at Gotland Museum (2006) (Photo by K. Mannermaa).

Fig. 7. Two-piece tubular bone artefacts 1637/6BN12, 1042/6BN12, 981/6BN12, 934/6BN12, 1458/6BN12, 959/6BN12 and 811/6BN12 made of the ulna and radius of a wild turkey (*Meleagris gallopavo*) from Eva (Photo by courtesy of McClung Museum of Natural History and Culture, University of Tennessee, Knoxville).

Fig. 8. A striated shaft in tubular artefact 34702 found separately in Ajvide grave 62 (the diameter of the swan [*Cygnus* sp.] radius is 8.2 mm) (Photo by J. Norderäng).

Fig. 9. A striated inner tube in artefact 811/6BN12 from Eva (the diameter of the tube is 5.6 mm) (Photo by R. Rainio).

Fig. 10. A rounded end of artefact 34647 from Ajvide grave 62 (the diameter of the end is 11.8 mm)

(Photo by J. Norderäng).

Fig. 11. A notched end in artefact 981/6BN12 from Eva (the diameter of the tube is 4.7 mm) (Photo by R. Rainio).

Fig. 12. A rounded and notched end in tubular artefact 34698 found separately in Ajvide grave 62 (the diameter of the swan [*Cygnus* sp.] radius is 7.9 mm) (Photo by R. Rainio).

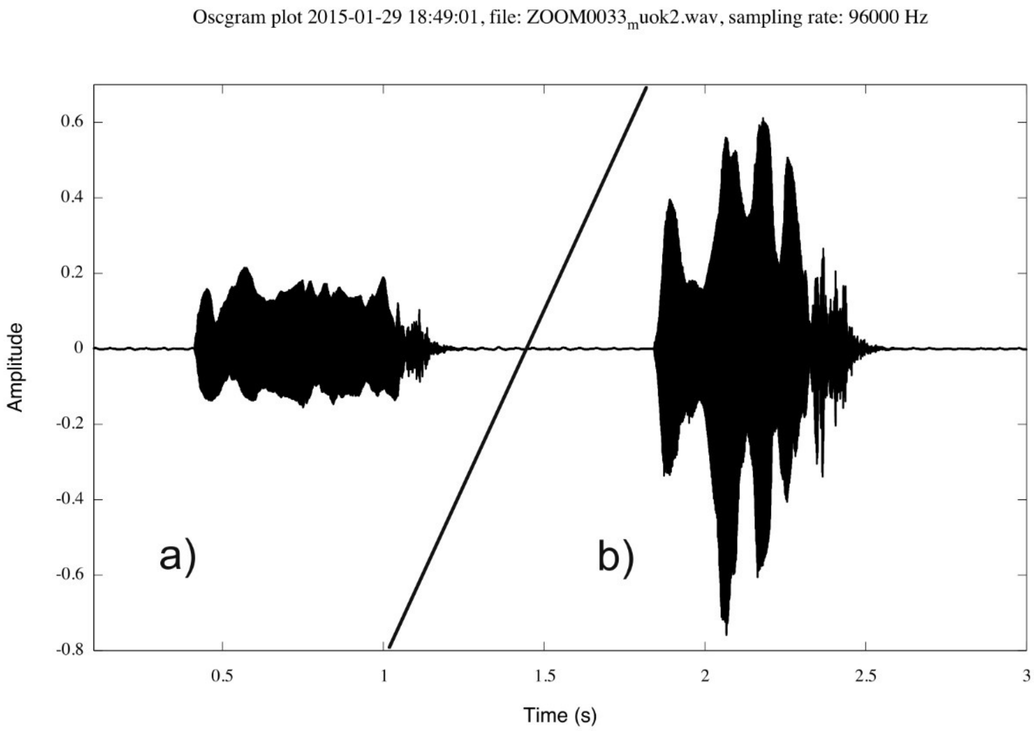

Fig. 13. Oscillogram showing the amplitudes produced by sucking a) a one-piece tubular artefact made of the radius of a swan (*Cygnus olor*) (L 114 mm), b) a two-piece tubular artefact made of the ulna and radius of a swan (*Cygnus olor*) (L 114 mm). A few seconds were clipped from the original sound file to compress the plot.

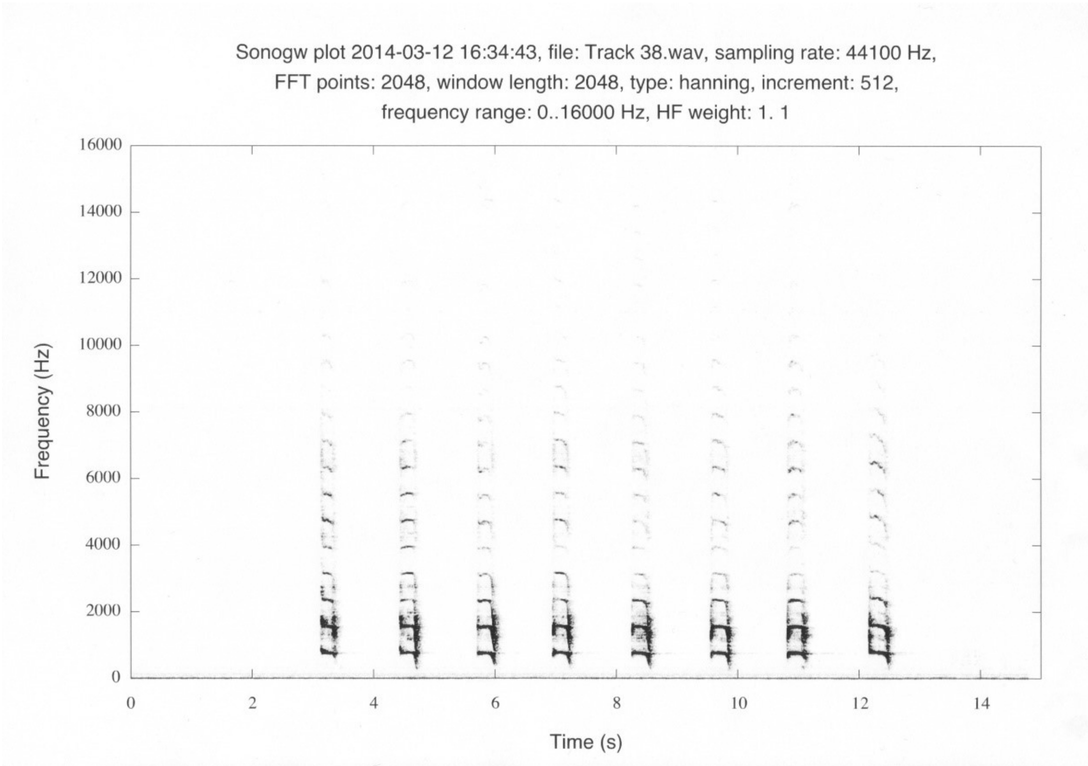

Fig. 14. Sonogram showing the sound frequencies produced by sucking a two-piece tubular artefact made of the ulna and radius of a swan (*Cygnus olor*) (L 114 mm).

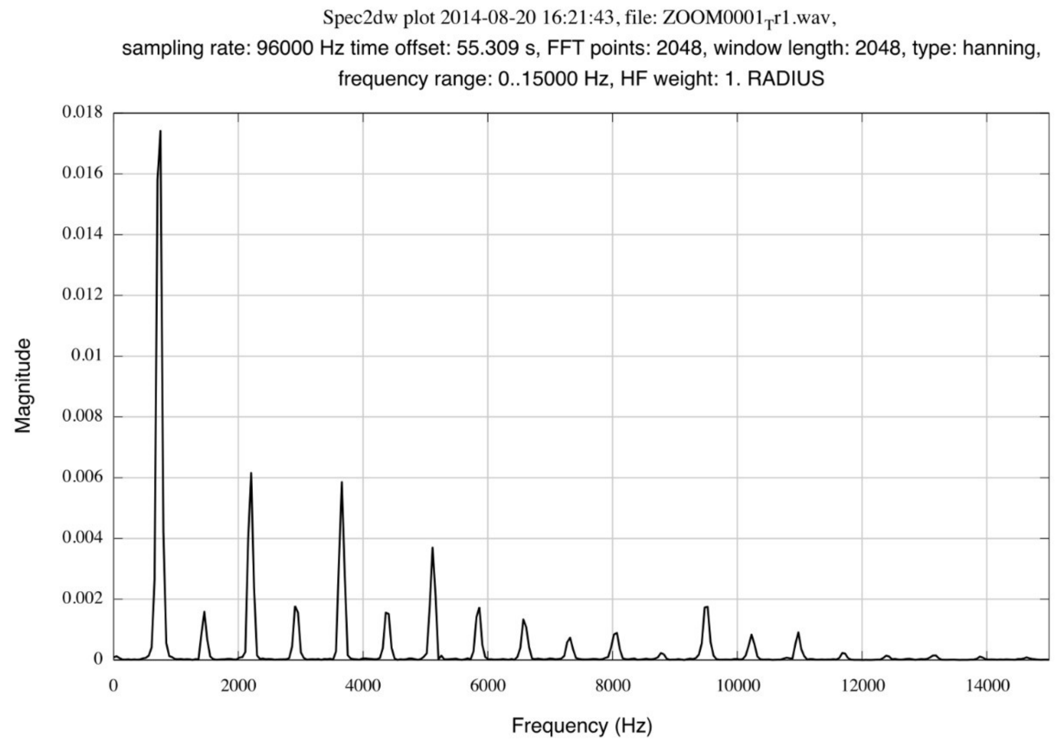

Fig. 15. Spectrogram showing the sound frequencies produced by sucking a one-piece tubular artefact made of a swan radius (*Cygnus olor*) (L 114 mm).

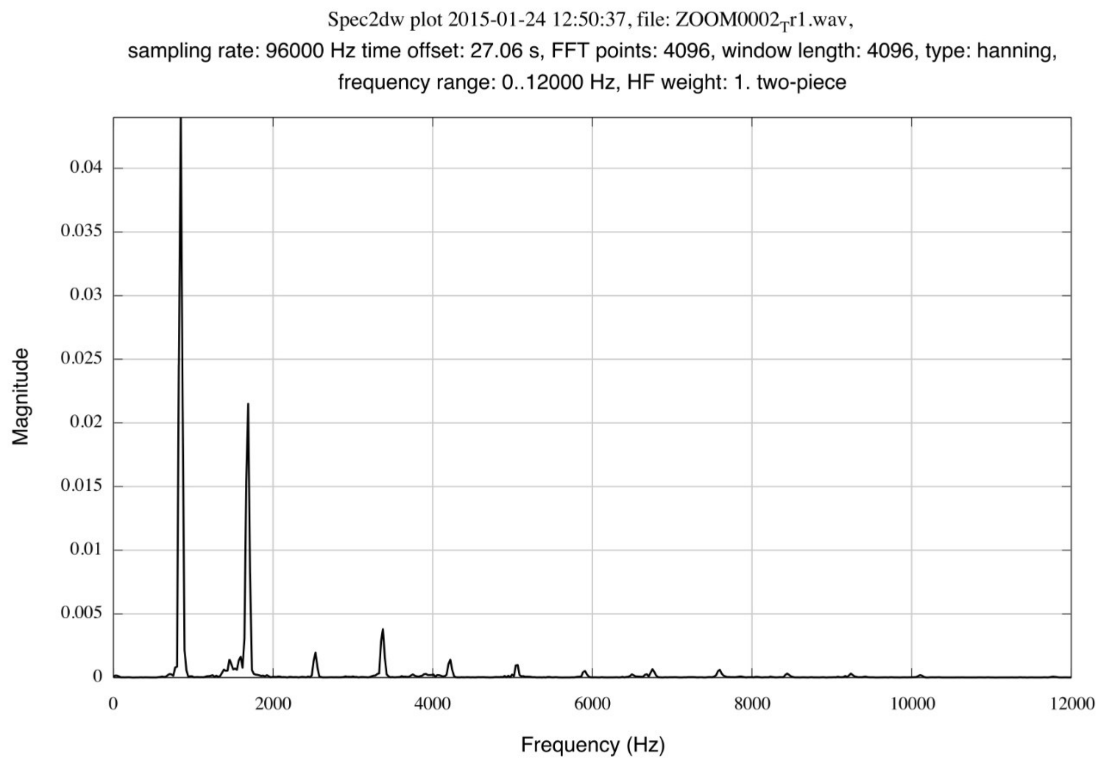

Fig. 16. Spectrogram showing the sound frequencies produced by sucking a two-piece tubular artefact made of the ulna and radius of a swan (*Cygnus olor*) (L 114 mm).

- 42 Aerophones proper
  - 421 Flutes
  - 422 Reed aerophones
  - 423 Trumpets (lip-vibrated aerophones)
    - 423.1 Natural trumpets
      - 423.11 Conches
      - 423.12 Tubular trumpets
        - 423.121 End-blown trumpets
          - 423.121.1 Straight trumpets → Nolkin (González 1986, 20)
            - 423.121.1–3 Blown trumpets
            - 423.121.1–4 Sucked trumpets (Schneider 1993, 79)
            - 423.121.1–5 Blown and sucked trumpets
          - 423.121.2 Curved or folded horns
        - 423.122 Side-blown trumpets
        - 423.123 Sucked trumpets (Schneider 1993, 79)
    - 423.2 Chromatic trumpets
    - 423.3 Sucked trumpets (Pérez de Arce 2013, Apéndice 21)
  - 424 Byrgys (Leisiö 1998, Fig. 1)

Tab. 1. Proposals for incorporating sucked trumpets in the Hornbostel-Sachs system of musical instrument classification.

Site	Catalogue no.	Artefact	Structure	Perforations	Species	Element	OD	ID	L	TL
Ajvide	34647	Two-piece tube	outer tube inner tube	Unperforated Perforated	*Cygnus* sp. -	ulna -	12.9 7.3	9.8 -	71.3 31.5	71.3
Ajvide	34648	Two-piece tube	outer tube inner tube	Unperforated Unperforated	*Cygnus* sp. *Cygnus* sp.	ulna radius	14.4 8.3	8.7 5.6	54.8 58.7	97.6
Ajvide	34649	Two-piece tube	outer tube inner tube	Unperforated Unperforated	*Cygnus* sp. *Cygnus* sp.	ulna radius	15.6 8.9	9.7 5.7	68.3 60.7	94.5
Ajvide	34703	Two-piece tube	outer tube inner tube	Unperforated Unperforated	*Cygnus* sp. -	ulna -	12.4 7.6	- -	69.4 60.3	tubes loose
Ajvide	34704	Two-piece tube	outer tube inner tube	Perforated Unperforated	*Cygnus* sp. *Cygnus* sp.	ulna radius	10.7 7.4	7.3 5.4	32.1 56.9	59.7
Eva	811/6BN12	Two-piece tube	outer tube inner tube	Unperforated Unperforated	*Meleagris gallopavo* *Meleagris gallopavo*	ulna radius	14.0 5.6	- 2.5	105.0 <93.4	112.4
Eva	934/6BN12	Two-piece tube	outer tube inner tube	Unperforated Unperforated	*Meleagris gallopavo* *Meleagris gallopavo*	ulna radius	10.0 5.1	5.2 3.3	>60.6 43.5	>73.8
Eva	959/6BN12	Two-piece tube	outer tube inner tube	Unperforated Unperforated	*Meleagris gallopavo* *Meleagris gallopavo*	ulna radius	11.4 6.7	7.5 4.1	>88.1 <74.8	>115.1
Eva	981/6BN12	Two-piece tube	outer tube inner tube	Unperforated Unperforated	*Meleagris gallopavo* *Meleagris gallopavo*	ulna radius	10.7 6.1	7.7 3.7	>74.2 55.5	>82.4
Eva	1042/6BN12	Two-piece tube	outer tube inner tube	Unperforated Unperforated	*Meleagris gallopavo* *Meleagris gallopavo*	ulna radius	11.5 6.7	7.5 4.1	>55.0 >92.2	tubes loose
Eva	1458/6BN12	Two-piece tube	outer tube inner tube	Unperforated Unperforated	*Meleagris gallopavo* *Meleagris gallopavo*	ulna radius	10.6 6.1	6.8 2.7	>41.7 <39.0	>51.7
Eva	1637/6BN12	Two-piece tube	outer tube inner tube	Unperforated Unperforated	*Meleagris gallopavo* *Meleagris gallopavo*	ulna radius	11.6 6.6	8.1 3.8	>81.4 113.4	>135.5

Tab. 2. Measurements, structure, and taxonomic and anatomical identifications of the study material. Abbreviations: OD = largest outer diameter (mm), ID = largest inner diameter (mm), L = length (mm), TL = total length of the artefact (mm). Symbols > and < indicate that the original length of the tube is lost due to the broken ends.

Artefact	Perforations	Species	Element	OD	ID	TL	L_{pA}
One-piece tube	Unperforated	*Cygnus olor*	radius	8.8	6.3	114.0	74.6 dB
Two-piece tube	Unperforated Unperforated	*Cygnus olor* *Cygnus olor*	ulna radius	12.0 8.5	9.4 6.7	114.0	83.4 dB
One-piece tube	Unperforated	*Cygnus olor*	ulna	11.6	8.4	114.0	83.4 dB

Tab. 3. Measured maximum sound pressure levels outdoors at an ambient noise level of 30–31 dB. Abbreviations: OD = largest outer diameter (mm), ID = largest inner diameter (mm), TL = total length of the artefact (mm), L_{pA} = A-weighted sound pressure level at a distance of one metre.

Tracklist

Track 1 (0:12 min).
Clucking sounds produced with a copy of artefact 811/6BN12 from Eva. Played and recorded by R. Rainio.

Track 2 (0:17 min).
Trumpeting tones produced with a copy of artefact 34648 from Ajvide. Played and recorded by R. Rainio.

Track 3 (0:21 min).
Trumpeting tones produced with a copy of artefact 34703 from Ajvide. Played and recorded by R. Rainio.